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Market Development of PV Solar Home System (SHS) and PV Pumping in Yemen

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Abstract: The Blockade of Yemen imposed by Coalition Led by Saudi Arabia led to a severe scarcity in fuel which caused the unavailability of electricity produced by fossil fuel-based sources such as diesel-based generation. Therefore, households and other energy consumers looked for all possible ways to get the power supply. Due to the disappearance of fuel, the installation of PV Systems was the best and survival solution. Consequently, rapid diffusion of PV Solar Home Systems (SHS) took place as well as PV Water Pumping. As a result of rapid demand increase, the PV SHS market suddenly emerged and experienced very high growth. Subsequently, most of the traders and even ordinary shops got into the business of selling PV SHS. Before the conflict, PV SHS sales were counted, in best cases, hundreds, now it has jumped up to hundreds of thousands. Thus, a large market for PV SHS was created within a year. Similarly, other energy consumers converted their source of energy into PV, mainly ground water pumping. This paper examines closely this phenomenon by means of market assessment using a pilot site survey that was performed on households, PV SHS dealers and PV Pumping dealers. Further a new approach was proposed to estimate the total installed PV peak power in the country.

Key words: PV, SHS, renewables, market development financial ability factor

1. Introduction

Since the start of the war in March 2015, the Saudi Led Coalition has imposed an embargo on many parts of Yemen. All oil products stocks were depleted within 6-8 weeks, resulting in the shutdown of all Public Electricity Corporation (PEC) power stations. Hence Sana'a and many cities and rural areas did not have power from Public Electricity Utility. In addition, the lack of fuel made it difficult to operate private generators. Therefore, households looked for other alternatives for power supply such as Photo Voltaic (PV) Solar Home Systems (SHS). Consequently, rapid diffusion of PV SHS took place, hence the PV SHS market suddenly emerged and experienced a very high growth that most of the traders and even ordinary shops got involved in PV SHS trade. Similarly, PV technology applications were diffused in other sectors like ground water pumping, shops, clinics, mosques, etc. This subject has been addressed by a number of studies and reports [1-5]. Although Maged Mahmoud et al. [5] covered well all aspects of the subject, however, the obtained results concerning the total installed PV peak power were not appropriately justified. The other References did not use any analytical approach.

This paper analyses this phenomenon, including market size, future growth and potential of the PV technology industry. The approach used in this work is a pilot site survey that was performed on households, PV SHS dealers and PV Pumping dealers.

The paper starts with a brief discussion of the survey model and survey outcomes. Then the Paper proposes a new concept to estimate the total installed PV peak power in the country. Next Challenges and Value Chain are presented. Finally, the work conclusions are derived and presented

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2. Survey

A survey was based on the following:

1) A residential quarter located in north-east of Sana'a called Saawan. The quarter contained 190 dwelling units, which is neither a high class nor a poor area, but it is rather a mixture of different levels of living standards. Thus, it is a suitable model for this study.
2) A sample of 72 traders, PV SHS importers and sellers were surveyed.
3) A sample of 15 traders of PV water pumping installations, having their projects spread over 17 governorates were surveyed.

2.1 PV SHS Dwelling Survey

A total of 190 dwelling units represent 190 Households (HH), were the subject of the questionnaire. Out of the 190 HH targeted in the survey, only 149 HH responded to the questionnaire and they confirmed that they used PV SHS. 17 HH confirmed that they have PV SHS, but they didn't want to respond to the questionnaire. The rest 24 HH did not have PV SHS in their houses.

2.2 Quantitative Outcomes and Calculations

The quantitative HH survey results and direct calculations are shown in Table 1.

The main takeaway points are summarized next:

- As shown in Fig. 1, the majority of PV SHS installed are 150 Wp panels. The graph has a nearly Normal Distribution shape.
- The total peak power installed in the HH who responded to the questionnaire, was 57.4 kWp.
- From Fig. 2, it shows that more than 50% of respondents had PV SHS with 300-400 Wp. The same could be true for the whole Country.
- The average peak power of PV SHS per HH is 385.235 Wp.
- The diffusion rate is 87.37%, which is considered very high. This includes the HH who have PV SHS but didn't respond to the questionnaire
- The overall average peak power for surveyed houses (AvWp) is 336.574 Wp.
- The total cost for these PV SHS peak power was found in US$12,963. This represents an average unit price of US$2.26/Wp and US$872.5/SHS.

Table 1 PV SHS dwelling survey results.

No	PV [Wp]	No of Panels	Total Installed [Wp]	No of Surveyed Dwelling Units	190
1	50	18	900	HH having SHS responded	149
2	100	86	8600	HH having SHS not responded	17
3	150	239	35850	HH not having SHS	24
4	200	42	8400	Diffusion Rate	87%
5	250	11	2750	Average Wp/HH	385
6	300	3	900	Overall Average Wp/HH	336
Grand Total		399	57400	Total costs PV SHS [$k]	130

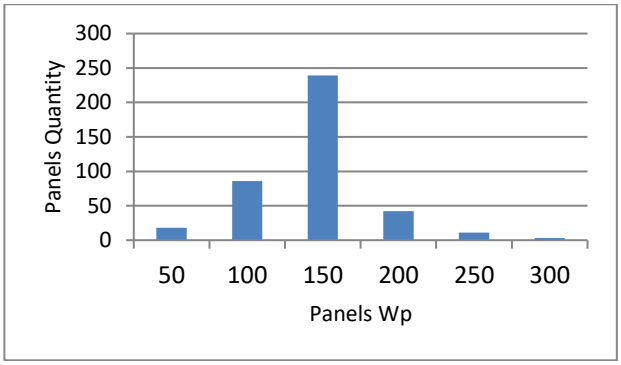

Fig. 1 Frequency distribution of panels Wp.

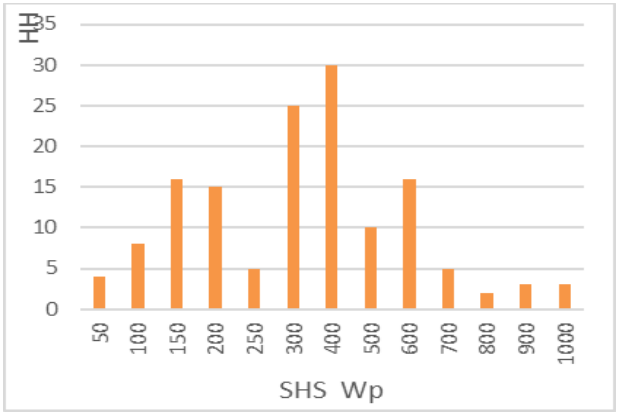

Fig. 2 Frequency distribution of HH Installed power.

- Due to the significant fall of the value of YR against USD in the second half of 2017 an average of YR300/US$ over the years 2014 to 2018.

2.3 Estimation of Installed PV Peak Power

The survey results can be used to estimate the installed PV peak power in Yemen. The following approach was used:

- The average dwelling growth rate is calculated from Ref. [6], for years 2004 to 2009.
- A new concept called "Financial Ability Factor (FAF)" based on HH expenditure on food and non-food goods and services taken from Ref. [6] is introduced here.
- Sana'a is assumed to be the "reference" in these estimations for the other areas for the following parameters: Urban Living Factor of Households is referred to "Sana'a City" and Rural Living Factor of Households is referred to "Sana'a rural".
- The diffusion rate of PV SHS for non-embargoed areas is 25% of embargoed ones.
- Peak power of PV systems used by non-HH (shops, clinics, mosques, street light, etc.) is assumed to be 15% of total PV SHS peak power.
- In order to perform the required calculations, the following steps were carried out:

✶ The Number of Dwellings in 2014 = number of HH in 2009 * $(1+gr)^n$; where gr is HH average growth rate = 0.029; n is number of years; in our case n = 5;

✶ The Financial Ability Factor (FAF), which is the HH expenditure of Urban (FAFu) and Rural (FAFr) areas, with respect to Sana'a City, FAF = (food and non-food expenditures)/(Number of Dwelling in 2009*FAF of Sana'a);

✶ The Average PV SHS peak power of different cities and rural areas = AUWp + ARWp = AvWp (FAFu * Du + FAFr *Dr*); Du & Dr are dwelling numbers of urban and rural areas respectively in 2014;

✶ The total installed peak power of PV SHS in Yemen is the sum of estimated peak power in all Governorates.

✶ The total number of PV SHS in the Country will be the Overall average peak power for each governorate*number HH in that governorate in 2014.

✶ The total Investment costs of PV systems installed in all governorates for HH and non-HH [Mil.$] = Total Installed PV peak power including other users*unit price of Wp.

An evaluation matrix was constructed, to carry out the above listed calculations (Annex 1) The essential results are given below:

- Total installed SHS peak power is 331.68 MWp;
- Peak power of PV systems used by non-HH (shops, clinics, mosques, etc.) @ 15% = 49.75 MWp;
- Total Installed PV peak power including other users but water pumping not included is 381.43 MWp;
- If PV peak power of water pumping of 65 MWp is added the Grand Total of Installed PV peak power is 435.18 MWp;
- Total Investment costs of PV systems installed in the Country is $983.49 Mil.

These figures show clearly the significant market development for PV technology applications took place in Yemen. In order to appreciate this development, let us compare the total Installed PV peak power with the total available capacity of electrical power of Public Electricity Corporation (PEC), which is the sole national Electricity Utility in Yemen. The total available power generation capacity owned by PEC is 960 MW [7]. As given earlier the total installed PV peak power could reach 435.18 MWp, or 45.3% of total available generation capacity of the

PEC. This is significantly higher than the average percentage of installed renewable capacity which rarely exceeds 10% in most countries [8].

2.4 Questionnaire Feedback

As mentioned earlier 149 HH responded to the questionnaire. The questionnaire contains various technical aspects of SHS, such as installation, operation and maintenance. Annex 2a contains the questionnaire results, as Table 2 summarizes HH feedback. It is clear from Table 2 that most of the HH responded positively to PV SHS experience, which took place during the war. However, it should be noted that the failure rate is quite high. Nevertheless, the majority of HH are satisfied with PV SHS.

2.5 Retailers' Survey

A total of 72 Retailers of PV SHS systems were surveyed. The questionnaire emphasis was mainly on: company info, PV SHS sales and stock and challenges facing this business. Table 3 contains a summary of PV SHS survey results. Annex 2b contains detailed survey results. PV SHS sales were not given by the retailers as they consider this data to be commercially sensitive and confidential. The top 9 surveyed retailers controlled approximately 50% of the market.

Table 2 Summary of HH feedback.

Question	Feedback	
System installation	By Technicians 93;	By Customer himself 56
Demand satisfaction of SHS capacity	Satisfied: 33;	Unsatisfied: 116
Conducting maintenance	Doing: 118	Don't: 31
Customer overall satisfaction	Excellent: 11; V. good: 48; good: 59; satisfactory 19; Unsatisfactory: 9	
SHS failures leading to a power cut off	Yes: 110	No: 39
Types of faults	Battery 50%; Panels 30%; controllers and connection 20%.	

Table 3 Retailers survey.

PV SHS Dealers' Survey				
Number of Retailers	Number of Panels in Stock	Peak Power of Panels	Total Peak Power of stock	Largest Market Share [%]
72	81783	50-340 Wp	17,633,375Wp	11.11; 6.1; 5.2

2.6 PV for Water Pumping

Groundwater is the main source for domestic usage, drinking and irrigation in Yemen. Due to the lack of fuel during the first year of the conflict, many Water Authorities and farmers replaced their diesel engine pump systems by PV pumping systems.

In order to assess the market development in this area, a survey was performed for PV pumping suppliers. Emphasis was given to the following parameters: Company data, Location of project, PV peak power [Wp], country of origin and cost. Table 4 summarizes the results of the survey. Unlike the HH SHS market, the largest retailer controls approximately 40% of the market share and the second more than a quarter of the market, indicating that there is less competition in this market sector than the PV SHS sector. It is interesting to note that the location covers almost all governorates, 17 out of 22. Also, the number of projects and the total peak power given in Table 4 could be greater as there are no official records for PV Pumping traders due to the Country's circumstances. Therefore, it is rational to assume that the capacity is higher by 20%. In other words, the actual total installed peak power for water pumping could reach 65 MWp. From the available price list, the unit price PV pumping system is $1.262634/Wp. Then the total investment would be $82M. Annex 2c contains the results of the survey sorted by market share.

3. Challenges

The instability and war in the country have strongly affected business. Consequently, major difficulties and challenges facing the PV market are created by these circumstances. The following points were taken from dealers' questionnaires, both PV SHS and PV Pumping:

Table 4 Summary of water pumping.

Number of Importing Companies	Number of Countries of Origin	Governorates where Pumps Installed	No of Pumps
15	15	17	1782
Peak Power [MWp]	Total Investment [Mil$]	Largest Market Share [%]	
53.746	67,863	39.5; 25.6; 9.7;	

- Continuous devaluation of local currency (YR) against foreign currencies.
- Increased taxes and customs levies; custom charges were doubled in northern and western governorates for goods imported through southern and eastern ports.
- Increased transportation costs.
- Delays at seaports.
- The customers have little knowledge and experience in dealing with the equipment.
- The rapid increase in the inflation rate.
- The restrictions on money transfer outside Yemen by local Banks due to the embargo imposed on Yemen.
- The price of high-quality PV systems has gone up significantly. The market is full of the low-quality cheap PV system.
- There are no regulations to monitor and control PV system import, hence the competition is not fair.
- There are difficulties in obtaining finance for PV Pumping Projects.
- Imports are almost blocked for years 2017 & 2018.
- Difficulties in opening Letters of Credit.

Apparently, most of the challenges are inherently created by war situation.

4. Value Chain

The value chain structure could look like the one shown in Fig. 3. A brief description for each element of the structure is giving next.

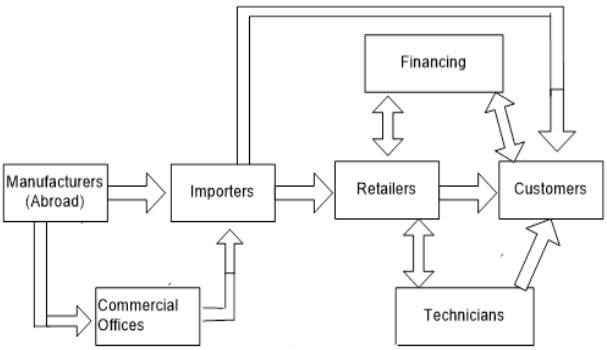

Fig. 3 Value chain.

4.1 Manufacturers

The PV technology industry in Yemen is almost non-existent except for metal frames and PV support structures.

4.2 Importers

In 2015, all ports and airports were closed by the Saudi Led Coalition. Most of the imported goods were delivered to the Country on land by tracks from the Gulf States, mainly the United Arab Emirates (UAE). In that year a rapid increase in demand took place (see Table 5). This situation enabled many businesses to be involved in PV technology.

Table 5 shows the PV systems import trend. Before the war in 2014, the total number of imported PV units from all ports was 24,478 units. Despite the embargo and the closure of the ports due to the war, there was a 10-fold increase in the number of imported units. This dramatic increase took place in order to meet the highly demand increase.

4.3 Retailers

For the same reason, a huge number of retailers became involved in the PV business. Market share of SHS, is discussed in Sections 3. The largest trader is Assaleh for Trading whose share was 11.11%, which shows healthy competition. The SHS and water pumping trader survey results are summarized in Tables 3 and 4.

Table 5 PV systems import (units).

Port of Entry	2014	2015	2016	Total
Sea Ports	23,117	143,833	113,797	280,747
Land Ports	1,138	325,386	326,115	652,639
Airports	223	287	00.0	510
Total	24,478	469,506	439,912	933,896

4.4 Financing

There are 11 financial institutions engaged in the PV business, see Annex 3 for more details.

There is no business model to finance PV projects. However, the financial institutions apply loan conditions that ensure the loans are paid back [5]. These conditions are summarized in the following points:

1) Private sectors employees should do the following:

- Sign agreement between the Employer and the financier
- The Salary of the Employee should be received through the financier
- Price quotation should be provided

2) Civil servants: Employees

The loan application must be supported by a guarantor.

3) Others:

They should deposit gold, commercial guarantee or cash as a guarantee.

This procedure reflects the economic and financial crisis created by the war. Consequently, it is not feasible to propose a personal business model, which could replace the above-mentioned procedure, until the war has ended.

4.5 Customers

As mentioned earlier a fast-transitional process of PV market development started in a few months after the conflict. It has resulted in the appearance of a wide spectrum of PV types, technologies, peak powers, manufacturers, countries of origin, prices, etc. in the market. The same phenomenon applies to PV SHS components; like batteries, controllers, inverters, etc.

Furthermore, the rapid increase in demand has led to a mess at the customer end of the Value Chain, for example, high system failure rates, low standard of goods, the big difference of prices, … etc. This was reflected in the questionnaire results. In addition, 78% of the respondents stated that PV SHS capacity does not satisfy household demand. The failure rates have reached 74%, which is significantly high. On the other hand, 40% of the respondents were highly satisfied.

5. Conclusions

This paper has developed a new approach to estimate installed power of PV SHS. The paper has shown the extraordinary market development of PV technology applications in Yemen, notwithstanding some of the problems such as the low quality of the PV systems in the market, the quality of the installations is not always up to an acceptable standard and the high prices. The paper showed also that the people of Yemen have used PV technology to mitigate the effects of the energy crisis during civil war.

It has been shown that the amount of installed PV systems is more than a 45% of PEC available generation capacity which is significantly high. It is clear that there is a high potential for further development of PV technology industry in Yemen. Since the diffusion is approximately 90% in Sana'a; it will be economically feasible to apply PV system grid parity when the power sector returns to its normal initial state. Further research can be initiated to achieve verification of proposed approach used here in estimation installed PV peak power.

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Annexes

Annex 1: (see attached excel file)

Annex 2a: HH questionnaire outcome (technical and non-technical):

- Who did the installation? → By Technicians 93; By Customer himself 56
- Does PV SHS capacity satisfy house demand? → Yes: 33; No: 116
- Does the customer carry out regular maintenance and checks, e.g.:

Cleaning Panels		Observing controller		Battery Check	
Yes	No	Yes	No	Yes	No
149	0	101	48	104	45

- Over whole Customer Satisfaction

Excellent	11
V. good	48
Good	59
Satisfactory	19
Unsatisfactory	9

- Is there any failures or faults causing PV SHS shutdown?

  Yes 110; No 39.

- Type of faults: Battery 50%; Panels 30%; controllers and connection 20%.

Annex 2b Dealer questionnaire outcome.

PV SHS Dealers Survey; Sorted by Greater Market Share				
No	Dealers	Panel Stock	PV [Wp] Stock	Market Share
1	Assaleh for Trading	7000	1960000	11.11%
2	Alwahbani for Trading	4000	1068000	6.06%
3	Alsonaidar for Trading	4000	915000	5.19%
4	Alashwal for Trading	3900	820000	4.65%
5	Brthrs & Yamani for Trading	3100	707000	4.01%
6	Aburrijal Corporation	2800	695000	3.94%
7	Computer Engineering World	3700	675000	3.83%

8	Violet flower for PV systems	3100	570000	3.23%
9	Spark Technology	2600	545000	3.09%
10	Aljazeera Electronics	3000	520,000	2.95%
11	Alqaifi	2300	520000	2.95%

Annex 2c PV pumping dealers survey; Sorted by greater market share.

No	Importing Company	Country of Origin	Governorates where Pumps Installed	Pumps	Peak Power	Market Share
				No	[MWp]	
1	Abdullah Ahmed Alsunidar for General Trading	Italia	Al-Hudaydah/Lahj/Amran/Hajjah/Aden /Dhamar	543	21.21	39.5%
2	Computer Engineering World	Canada/Italy/Germany /India/Taiwan/China	Al-Hudaydah /Saadah and Different areas	510	13.75	25.6%
3	Bin Yassin Trading Est. - Solar energy pumps	Switzerland/India	Al-Hudaydah /Dhamar/Sana'a/Ibb/Lahj	301	5.21	9.7%
4	Green Energy Centre	Japan and Denmark	Al-Hudaydah/Sana'a/Dhamer/Hajjah/Ibb/ Taiz/Hajjah	57	4.56	8.5%
5	Jerusalim for Import	Spain	Al-Hudaydah/Dhamar/Sana'a/Albaidha/ Taiz/Hadramout/Ibb/Mareb/Rada'a /Hajjah	102	3,81	7.1%
6	Alwadi Energy Company	China/India	Hadramout/Valley and Coast	51	1.56	2.9%
7	Technical Supplies Center (TSC)	Germany	Al-Hudaydah/Sana'a/Dhamar/Hajjah /Amran /Lahj/Shabwa/Ibb	138	1.24	2.3%
8	Ghamdan Trading & Services	China	Al-Hudaydah/Sana'a/Amran/Dhamar /Aldhalea	27	1	1.7%
9	Energy Power Int.	China/India	Al-Hudaydah/Lahj	21	0.63	1.2%
10	Systems and Solar Energy Company	China/India	Shabwa, Lahj and Hadramout	14	0.38	0.7%
11	Smart for Technology	Korea/Malaysia /Germany	Al-Hudaydah/Rada'a/Taiz/Dhamar	6	0.195	0.4%
12	Albasha Power Solution	Italia	Al-Hudaydah/Sana'a/Saadah	6	0.168	0.3%
13	Frist Power	French/Phanzolli/ Chinese/United Arab Emirates	Al-Hudaydah/Dhamar	2	0.82	0.2%
14	Ebrahi Ishaq for Trading	Denmark/Italy	Al-Hudaydah/Saadah	2	0.69	0.1%
15	Aidaroos for Solar System	China/India	Abyan.Lahj	2	0.07	0.0%
	Total			**1782**	**53.755**	

Annex 3 List of financial institutions

1) Small Enterprise Development Fund (SEDF).
2) Yemen Bank for Reconstruction and Development-Islamic Branches.
3) Cooperative and Agricultural Credit Bank-CAC Bank.
4) Tadhamon International Islamic Bank.
5) Cooperative and Agricultural Credit Bank-Islamic Branches.
6) International Bank of Yemen.
7) Yemen Commercial Bank.
8) Al-Amal Microfinance Bank.
9) National Microfinance Foundation.
10) Alkuraimi Islamic Microfinance Bank.
11) Azal Islamic Microfinance Program.